Microgravity Liquid Containment Vessel

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Numerous protein crystal growth experiments performed in microgravity have been degraded due to the existence of air bubbles within the liquid solutions. Other materials processing and fluid experiments flown on Space Shuttle missions have encountered similar problems. The origins of most of these bubbles were generally unknown, except where leakage was an obvious cause.

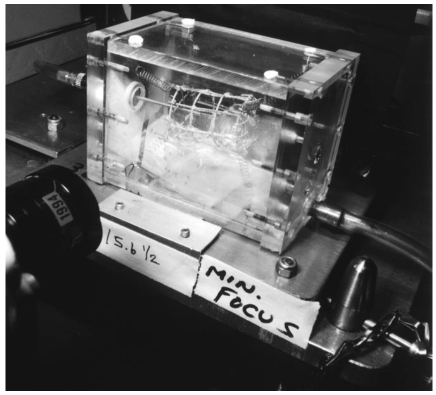

FIGURE 147.—A test photo of one of the cages being filled during a low-G parabola.

To study this problem, a variety of liquid-handling experiments were developed by Dale Kornfeld at MSFC and Dr. Basil Antar at the University of Tennessee Space Institute and flown aboard the NASA KC–135 aircraft during the last 3 years with a specific purpose of understanding the conditions that lead to incipience and growth of unwanted bubbles during liquid-handling operations in microgravity. These procedures included the filling of various empty containers with liquid, liquid jet-impingement on a vessel wall, stirring of a partially-filled container, geysering in a liquid pool, and several others, all using liquids with different surface tensions. Each liquid injection or agitation was recorded using high-speed movie film and was performed during an aircraft parabola providing ~20 sec of low-g (~10^{-3}). Approximately 40 parabolas could be flown in one day. Postflight analysis of the film revealed that in almost all cases the bubbles formed were either folded into the liquid bulk during breakup of the gas/liquid interface, or they originated from trapped gas voids at the corners of the vessel, or from wall defects as liquid spread along a wall.

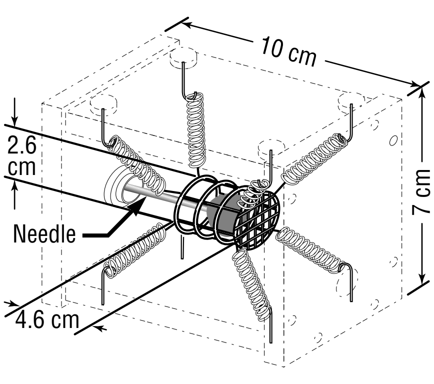

FIGURE 146.—Drawing of a typical "cage" tested during many parabolas on the NASA KC–135 aircraft.

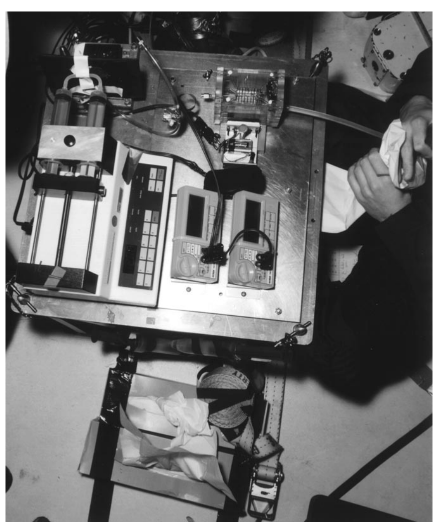

FIGURE 148.—A photo of test work as flown aboard the NASA KC–135 aircraft.

Results from these flights led the investigators to invent a novel design for a low-gravity liquid containment vessel which will minimize bubble formation while being filled. The primary feature of this vessel is the absence of walls and corners; the new vessel consisting only of an open-weave mesh. Solid walls are not necessary for liquid containment in microgravity, since the surface tension force becomes the most dominant force. The air-liquid interface, pinned by the mesh, in effect becomes the wall. This type vessel, actually a three-dimensional "cage," whose shape and volume are defined by a thin mesh is fully adequate for containing liquid volumes while in microgravity. Both plastic and wire mesh cages of various sizes, with gaps from 1/8- to 1/2-in between each mesh strand, have been tested during low-G parabolas and were found to easily contain liquid indefinitely at 10^{-2} G or lower, and to even contain liquid during transients of ~10^{-1} G.

In addition to bubble minimization, numerous other benefits over solid-wall containers are suggested, i.e., investigators will have easy access to all parts of a fluid volume while in microgravity for sample withdrawal or injection; equilibration of vapor pressures when the cage is inside a larger containment box, etc. A cage-container would be useful for solution crystal growth experiments in general, and protein crystal growth experiments, in particular.

Antar, B.N.; Kornfeld, D.M.: "Bubble Generation During Low-Gravity Fluid Handling Procedures." AIAA Paper no. AIAA-95-0878, January, 1995.

Kornfeld, D.M.; Antar, B.N.: "Bubble-Free Containers for Liquids in Microgravity." *NASA Tech Briefs*, vol.19, no.12, p.91, December 1995.

Antar, B.N.; Kornfeld, D.M.: “Gas/Liquid Flows During Low-Gravity Fluid Handling Procedures.” AIAA Paper no. AIAA-96-0502, January, 1996.

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Biographical Sketch: Dale M. Kornfeld is a chemical engineer, AST Aerospace Polymeric Materials, in the Space Sciences Laboratory. Kornfeld currently is lead scientist and engineer on the low-gravity bubble generation experiment, flown 15 times on a NASA KC–135 low-gravity aircraft. He has served as a mission scientist team member on three Marshall-managed Spacelab missions and has received numerous awards, including a NASA Inventor of the Year award in 1984.